IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: VARRIANO-MARSTON, Elizabeth — Group Art Unit: 1772

Serial No. 09/877,757 — Examiner: Patterson, Marc

Filed: 06/08/2001 — Atty. Dkt. No: MARS93-DIV

For: REGISTERED MICROPERFORATED FILMS FOR MODIFIED/CONTROLLED ATMOSPHERE PACKAGING

To: Box Non-Fee Amendment
U.S. Patent and Trademark Office
P.O. Box 2327
Arlington, VA 22202-0327

Fm:

Dear Honorable Commissioner:

This declaration is offered in support of the above application for patent.

RULE 132 DECLARATION OF ELIZABETH VARIANO-MARSTON (37 CFR 1.132)

I am the sole proprietor of EV Marston & Associates, a successful New Hampshire business that provides consulting services to many companies throughout the United States. I primarily develop breathable packaging materials for fresh produce (hereafter, fruits, vegetables, flowers, herbs), and consult with fresh produce companies on packaging and quality issues. For 11 years, I published a monthly newsletter, Produce Technology Monitor, a widely read newsletter in the fresh-cut produce industry. According to the trade, this newsletter is ". . . the bible for technical processing questions."

I have extensive experience developing breathable packaging materials for fresh produce. In this connection, I have developed polymer compositions for specific end uses, and developed breathable patch technologies and microperforated films - all for use in the fresh produce industry. These breathable packaging materials are currently being used by businesses to package fresh produce for quality retention and shelf life extension.

I am a member of a number of professional organizations, in or related to the food industry, including Institute of Packaging Professionals, Women in Science, Institute of Food Technologists, Produce Marketing Association (PMA), and International Fresh-cut Produce Association (IFPA). In addition, I have served on the Technical Committee of the IFPA, presented talks on produce packaging at national IFPA and PMA meetings, and served as an expert witness in one arbitration (*Dominos Pizza v. Fresh Prep*) and one civil proceeding (*Del Monte Corporation v. Del Monte Fresh Produce Company*) regarding fresh produce definitions, quality and fresh produce packaging. Based on my testimony for Del Monte Fresh Produce Co., the company won their case and was able to continue their start-up business in fresh-cut fruit, a business that is worth many millions of dollars for the company today

I began working on packaging films for fresh produce in 1983 while employed by Hercules, Inc. (Wilmington, DE), a major manufacturer of packaging films. From 1984 -1990, I was part of a Corporate R&D team (and became project manager for the team) that developed the first breathable packaging system for high respiring fresh produce items. The system consists of a permeable patch over a hole (aperture) in a package. In 1989, this packaging system won the R&D 100 Award and the DUPONT Award for innovations in food packaging.

In 1990, I began a consulting company to assist fresh produce companies with package development and specifications. In 1992, I began conducting research on the use of microperforations for controlling the atmosphere inside fresh produce packages.

<u>Background of the Invention</u>.

In the early to mid-1990's Courtaulds (UK) was beginning to market laser microperforated films to European companies. However, many produce companies that had tried these laser perforated films were unsatisfied because of inconsistencies in the oxygen transmission rates of the films. Inconsistencies were caused by Courtaulds' inability to reproducibly place the same number and size of microperforations in each bag and by blockage of the perforations by produce inside the bag, by marketing labels placed on the package, or by package-to-package contact that caused occlusion of the microperforations when bags were placed in case cartons for shipping. Furthermore, the sizes of the microperforations were so small that it was essentially impossible for the fresh produce

packer to know where the perforations were so they could avoid occluding them with produce and/or labels. In fact, the produce packer did not have an easy way to verify that the films they received were microperforated at all. The difficulties were related to the microperforation process employed by Courtaulds, wherein their process produced rows of very small (averaging 50 micron) microperforations along the entire machine direction of the film web.

Knowing the drawbacks and disadvantages of the Courtaulds' microperforated films, I decided that one remedy would be to increase the microperforation size and to <u>register the microperforations in a small identifiable area</u> (a defined area or window usually less than 2 sq in.) typically in the uppermost regions of the package by coupling lasers with optical sensor technology. Such a system would allow the customer to easily locate the microperforations for verification and prevent occlusion of the microperforations by product or labels.

The other problem with Courtaulds' microperforated films was that they were not specifically designed for the varying respiration rates of different fresh produce types and weights. The same microperforated film was often recommended for produce items of widely varying respiration rates. For example, they used the same perforated film for packaging the same weight broccoli and cauliflower, produce items that have a 2-fold difference in respiration rates. My vast database of knowledge on respiration rates of produce coupled with a method to calculate the number and size of microperforations needed to establish an optimum oxygen and carbon dioxide atmosphere inside the package made it easy to match the packaging material oxygen transmission rates with the respiration characteristics of each produce item and use that information to make and register the microperforations using laser technology.

<u>Present Invention</u>

One aspect of the invention relates to <u>registered microperforated packaging materials for use in modifying or controlling the flow of oxygen and carbon dioxide into and/out of a fresh produce container (flexible, e. g. bags, or semi-rigid), where the microperforations are specifically tailored in size, location and number for the specific produce</u>. The packaging system designates specifically tailored microperforated containers for particular fresh produce to optimally preserve the produce. The method of making the registered microperforations on the packaging material consists of using

a CO_2 laser and a sensor or timer mechanism in conjunction with processing that calculates the appropriate number/size of the microperforations to reach desired O_2 and CO_2 concentrations inside the fresh produce container during cold transport, storage, and display. Examples of the microperforated films are provided herein to show the location, size and number of microperforations for the various respiring produce. Exhibit A is included to show the differences between the De Moor (U.S. Pat. No. 6,013,293) microporous patch technology and the microperforated packaging as described in my patent application. Clark (U.S. Pat. No. 6,376,032) is yet another microporous packaging invention – which is the equivalent of comparing apples to oranges – as they are different technologies in their own field.

Exhibit A – is a Markon broccoli floret bag made of 2 mil PE base film with the <u>microporous</u> patch affixed to the film as taught by the De Moor patent. The patch allows the air to escape through the apertured cover member.

Exhibit B – shows the Markon microperforated 2 mil PE bag for broccoli florets according to the present patent application with microperforations of a specific size/number according to the optimal respiration rate of broccoli and placed in a target area in the uppermost portion of the bag.

Exhibit C – illustrates the target area as described in the present application where the microperforations are registered by the eye mark on polyethylene coextruded roll stock.

Exhibit D – shows the old technology with <u>microperforations not registered</u> and merely placed in a linear path along the entire film web. Once the bag is formed from this web, some portion of the non-registered microperforations are subject to occlusion and therefore, the rate of oxygen transmission is not consistent from bag to bag.

Exhibit E – shows microperforations in a target area according to the present invention to minimize the effects from occlusion on bags made from polyethylene monoweb.

Exhibit F – bags made of 1.2 mil BOPP (biaxially oriented polypropylene) with a heat seal coating with the microperforations in a target area according to the specifics of the present invention.

Exhibit G – bags made from seven-layer coextruded polyethylene with microperforations in target area according to the present invention.

Exhibit H – polypropylene/polyethylene laminated bag with targeted microperforations according to the present invention

Exhibit I – heat-sealable lidding films with microperforations according to the present invention.

Exhibit J – semi-rigid lid with microperforations in a targeted location to avoid occlusion by the center label.

The Exhibits visibly demonstrate the use of the microperforations with varying size/number that are placed in certain areas to avoid occlusion. The Exhibits illustrate the microperforated technology used on a number of differing materials including semi-rigid containers and heat-sealable lidding films.

Copying by the Inventive Subject Matter after product in use:
Pursuant to a license agreement with Roplast Industries (Oroville, CA), my proprietary microperforation laser drilling technology and microperforation specifications were used for a variety of produce items. Again, as part of the licensing agreement, EV Marston instructed Roplast on how to calculate the size and number of perforations required for specific fresh produce items to obtain the desired oxygen and carbon dioxide levels inside the packages. In return for my proprietary technology, Roplast was to pay for the use of the technology once microperforated materials were made and sold.

After Roplast terminated its business agreement with EV Marston, EV Marston obtained microperforated bags from New Star Fresh Foods (Salinas, CA) produced by Roplast using the laser equipment and proprietary information transferred to them by EV Marston. The microperforations were registered within a 2 in^2 area and had diameters within the size range that was specified for them by EV Marston. Based upon careful examination and inspection, it was conclusively

determined that Roplast was using proprietary technology belonging to EV Marston to market registered microperforated film with Landec, EV Marston's competitor. Litigation counsel was retained and notification was sent to Roplast. As a result of the steps taken by EV Marston, Roplast suspended production of any microperforated materials.

EV Marston has also discovered that the present owner of Courtaulds' microperforated films, Danesco, is registering microperforations on films made in the UK and sold in the U.S. The old Courtaulds' films had the microperforations continuous along the machine direction of the film. These old films were made before 2000, and before the EV Marston microperforated materials were being used in the industry. In addition, another potential infringer has been detected in the marketplace. Notification was sent to this company by legal counsel and we are presently waiting for a response.

Patent Protection

A provisional patent application was filed May 4, 1999 claiming the proprietary technology developed by EV Marston, which was protected from disclosure by the various agreements. The provisional application was filed within one year of any sale, offer for sale, public use or other statutory bars. It was filed before any of the initial efforts that began at Roplast in developing the invention. The subsequent Utility patent applications cover the inventive subject matter including additional proprietary technology developed. On Aug. 27, 2002, the first Utility Patent Serial No. 6,441,340 issued.

Response to Office Action dated 7/18/2002

There were several areas in the Office Action that requested further information on the technology related to the present invention. The accompanying materials are included as an aid to gain a better understanding of the technology related to packaging and the terms used in the art. They are also used to distinguish my invention from the state of the art.

Figure 1

Figure 1 a, b shows the microperforated film in a drawing perspective illustrating that the microperforations go completely through the materials and thereby provide a direct path between

the internal bag atmosphere and the external atmosphere. The size/shape/number of the microperforations controls the rate of gas interchange between the internal and external atmospheres. Figure 1c is an actual light micrograph of a 120 micron diameter hole made in a packaging film by the laser.

Figure 2

This figure helps to show the microporous films described in the prior art. In particular, note that there are no direct holes connecting the inner atmosphere to the external atmosphere. Instead, a torturous pore structure exists, resembling a sponge with a network of interconnecting pores. Gas flow through this porous structure, with its interconnecting polymer layers, occurs by a process of diffusion through each polymer layer that makes up the walls of the pores, until it finally reaches the other side of the film.

The Continuation of Figure 2 illustrates a cross sectional view of the microporous film indicating the convoluted path along the layers and voids in the film.

Text Articles

Heal-Sealable materials – *The Wiley Encyclopedia of Packaging Technology*, published by J. Wiley & Sons; pages 458-459, section entitled Multilayer Flexible Packaging
As noted in the description, the terms 'heat-sealable and 'sealable films' are well known and depicted in the prior art. Heat sealing refers to the melted sealing of packaging material through heat and pressure. Various techniques and products are described in the prior art.

Lidding – *The Wiley Encyclopedia of Packaging Technology*, published by J. Wiley & Sons; pages 440-442, section entitled Lidding
The lidding process refers to sealing containers, such as semi-rigid containers, to seal the contents within the container. A further description is detailed in *A Handbook of Food Packaging*, pages 136-137. The lidding processing and general configuration is shown in the thermoformed packs of Figure 4-46.

Semi-Rigid - *The Wiley Encyclopedia of Packaging Technology*, published by J. Wiley & Sons; pages 201-203, section entitled Coextrusions for Semirigid Packaging

Semi-rigid structures are known in the industry and one is further provided as an exhibit herein.

Test Data Comparisons

Bananas. The effectiveness of packaging materials made by the inventor's microperforation method (tradename = Micro-CAP™) in extending the shelf life of fresh produce has been compared to films commonly used in the fresh produce industry. Attached is a report by Mr. Manny Zantua from Aug. 1, 2001 (LETTERS 4,5), Del Monte Fresh Produce Company, on the shipment of bananas in Micro-CAP bags with the optimum size and number of microperforations registered in the uppermost 1/3rd of the bag compared to bananas packed in industry standard bags (Banavac™ bags) that are not perforated. The ship tests showed that bananas packed in Micro-CAP bags not only eliminated the need to tear open each bag before initiating ripening with ethylene gas, but also the microperforated bags delayed the color development by 2 days, i.e. control bananas in Banavac bags were color stage 3 (part green, part yellow) after 5 days while bananas in Micro-CAP bags were stage 3 after 7 days. In early studies with Del Monte, their VP of R&D, Dr. Daniel Funk, was surprised by the results of trials on the inventor's microperforated bags, as he writes in a hand-written note at the bottom of a Jan. 4, 1999 memo from Mr. Zantua (LETTER 1) and a Jan. 12, 1999 letter to EV Marston (LETTER 2). These later two letters provide further evidence from a scientist with extensive experience in produce packaging of the unexpected results obtained from the microperforation system of the present invention.

Green Onions. In developing the specifications for a particular produce items, preliminary tests are necessary to determine the optimum oxygen transmission rate requirements of the produce. A series of such tests were conducted on whole green onions packaged at Boskovich Farms (Oxnard, CA), and the data are summarized in the attached report (LETTER 3) from SOCOPAC, a sales agent working with one of the plastics converters who is licensing my microperforation method. The results show that green onions packaged in Micro-CAP liner bags that were designed with lower oxygen transmission rates (Micro-CAP B and C) maintained good quality longer than green onions packed in mechanically perforated bags.

The inventor's packaging method has also proven to be more effective than other packaging materials in extending the quality and shelf life of such items as soul greens (collards, kale, mustard, turnips), broccoli florets, cauliflower florets, and sweet cherries. I am intimately familiar with the prior art patents and commercial products and process, including De Moor US 6,013,293. To the best of my knowledge, I was the first to design and implement a working microperforation system, process and microperforated product with registered target area in the industry.

The undersigned declares that all statements of his own knowledge made herein are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application of any patent issuing thereon.

Respectfully submitted,

Elizabeth Varriano-Marston
Elizabeth Varriano-Marston

10/16/02
Date

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materials provides a wide degree of formulating flexibility to achieve adhesion to different substrates, heat resistance, chemical resistance, and barrier to migration of components of some products. Because of this formulating flexibility, less demanding applications can be served by lower-cost formulations.

Waterborne acrylic emulsion adhesives are being used in greater quantities than before to achieve compliance with EPA regulations (see Acrylics). Waterborne PVDC adhesives are also used to some extent, although efforts to develop PVDC adhesives that provide both good adhesion and good oxygen barrier have not been successful. These two characteristics reflect direct opposites in the chemistry of these materials. One can expect good, but not excellent, adhesion and good oxygen barrier with selected PVDC adhesives.

Extruded adhesives. Polyethylene and ethylene copolymers are widely used as laminating adhesives. They provide adhesion between substrates, add bulk to the lamination, and contribute to moisture barrier in the absence of foil. Polyethylene, EAA, EMA, EMAA, and ionomers are all used, depending on the substrate, bond strengths required, and end use. Polyethylene often requires the use of an adhesion promoter on one or both substrates. Nonpolar PE does not adhere to the polar surfaces of most traditional laminating materials. PE extrusion lamination is accomplished by using high extrusion temperatures to oxidize the surface molecules to some extent, which introduces a polar configuration. The polar ethylene copolymers adhere well to a variety of substrates. EAA, EMA, and ionomers have particular affinity for foil.

Waxes and wax blends. Paraffin or microcrystalline waxes, or both, are used for special applications where high bond strengths and heat resistance are not required (see Waxes). These materials can be modified by the addition of low molecular weight PE, EVA, or other resins and resin additives to increase adhesion, hot tack, and stiffness or softness of the lamination. They are generally applied to one of the substrates by gravure–cylinder application (see Coating equipment) at temperatures high enough to reduce the viscosity of the material within a range that can be adequately controlled by gravure. The second substrate is brought in contact with the hot wax under pressure, and the composite is chilled. If one of the substrates is very porous, the wax is chilled on the primary substrate before the combining operation. Examples of the use of wax as an adhesive include AF/wax/tissue chewing gum wraps; CELLO/wax/AF–modified wax for cheese packaging; and glassine/modified wax/AF/PE for a tobacco pouch.

Miscellaneous adhesives. A small number of laminations utilize the thermoplastic nature of a coating, which is a component of one or both substrates. For example, two films that have a heat-sealable PVDC coating can be joined with heat and pressure, or aluminum foil can be laminated to a prewaxed tissue by the application of heat and pressure. Printing inks can also serve as adhesives if the bond-strength requirements are limited. This technique is used in some PE–PR–PE laminations for chub packs (see Chub packages).

Package Closure

The methods of package closure are heat sealing, cold sealing, and glue sealing.

Heat sealing. The primary method of closing multilayer packages is heat sealing (see Sealing, heat). The inner component of the structure is a thermoplastic material that softens with application of heat and solidifies when the source of heat is removed.

Cold sealing. Heat is not necessary if the coating is a modified-rubber-based material that seals to itself with the application of pressure, but not to other materials. These are called cohesives, or cold-seal coatings (see Adhesives). They can be applied over the entire material surface, but they are most commonly applied as a peripheral coating at the edges of the material in register with a printed design on the package face. This is done to reduce materials cost, but also because cohesive materials have very high coefficients of friction. Reducing the covered surface area facilitates movement over the packaging equipment. Lap-seal applications are not feasible with cold seals because the cohesive would have to be coated on both sides of the material, which would result in sealing in the rolls. Care must be exercised in the processing of cold seal materials to reduce the possibility of off-odors affecting the product. Cold-seal materials are used to package ice cream, confections, and candy bars that would be damaged by heat.

Glue sealing. This involves the application of an adhesive (glue) to specific areas of the packaging material on the machine that forms the package (see Adhesive applicators). Glue sealing is not widely used for multilayer flexible packaging, except for products that do not require continuous seals and only on paper-containing packaging materials. The adhesive is partly dried by absorption of the water from the glue into the paper.

Heat-Sealable Materials

The success of multilayer flexible packaging is directly related to the use of heat sealing, which involves positioning the faces of the materials so they will be combined by melted sealant upon application of sufficient heat and pressure. This is dependent on the solidification of the sealant material when the heat is removed.

Heat-seal coatings. Heat-seal coatings are generally defined as coatings applied from solvent solutions or water emulsions. The coating weight is generally between 1 and 5 lb/3000 ft^2 (0.45 and 2.3 kg 278.7 m^2). Coatings on films and paper can be vinyl acetate–vinyl chloride copolymers, nitrocellulose, acrylics, or PVDC. PVDC coatings can provide barrier as well as heat seal (see Vinylidene chloride copolymers), but those formulated for maximum barrier properties are not heat-sealable. They are used as inner components of a lamination or on the outside surface. Vinyl chloride–vinyl acetate copolymers have been used for some time as heat-seal coatings on films and foil. They also protect aluminum from corrosive agents present in many products. Structures of this type are generally used as lid stocks (see Lidding) for rigid containers or as the closure portion of pharmaceutical pill packages. Emulsion coatings of low molecular weight EVA copolymers are used as the heat-seal component of lid stock for cups. Other heat seal coatings include waxes, nitrocellulose, eg, on cellophane, and acrylics, eg, on BOPP.

Waxes. Wax heat-seal coatings on paper also provide moisture barrier (see Waxes). Paraffin and microcrystalline waxes are used for sealing, as well as blends of the two. Waxes are available with a range of melting points, and care must be taken to choose a wax or blend that will achieve the desired sealing characteristics without blocking or sticking in the rolls. Waxes and wax blends can be modified with low molecular weight LDPE to harden them slightly. This makes them

ARTICLE 1

less susceptible to blocking, and it also strengthens the heat seal. Low molecular weight EVA added to waxes tends to improve the hot tack, seal strength, and resistance to blocking in roll form. Other tackifiers can be added to make the seals more tenacious. Wax coatings are sometimes applied on the packaging line. Some carton liners are heat sealed through the use of a wax stencil applied on the packaging machine to supplement the wax contained in the packaging material or to areas where no wax sealant is applied by the materials producer. This is primarily done on the foil surface of AF/wax/tissue laminations.

Hot melts. Hot melts, applied in molten form, utilize a number of thermoplastic resins, waxes, and modifiers. They are applied as coatings over the entire packaging material surface or in a pattern, registered with printing, to effect positive package closure. Hot melts can be formulated with one of a number of resins as the principal component, eg, ethyl cellulose, nitrocellulose, EVA, or polyamide.

Heat-sealant films. Most heat-sealant films are polyolefins.

Low density polyethylene. The most common heat sealant is low density polyethylene. This is not a single product, but a family of materials that vary in density, melt index, and molecular weight distribution (see Polyethylene, low density). As density increases, sealing temperature, heat resistance, strength, and stiffness increase, and sealing range, clarity, and barrier decrease. The differences are relatively minor within the range of low density polyethylenes.

Melt index has a more significant effect. As melt index increases (molecular weight decreases), sealing range and clarity increase, and sealing temperature, heat resistance, strength, stiffness, and chemical resistance decrease. Barrier properties are not affected. In general, polymers with melt index from 0.24 to 5.0 are used for manufacturing blown films, and those from 2.0 to 30.0 for cast films and extrusion coating. Molecular weight distribution (MWD) is a function of the polymerization process. Narrow MWD resins have a narrower sealing range than broad-MWD resins.

The range of polyethylenes provides great latitude in tailoring structures to meet package/product requirements. They are incorporated through film lamination, extrusion coating, or as components of coextrusions. The density of linear LDPE is within the range of conventional LDPE, but some of the properties tend to be more like HDPE. Compared to LDPE, for example, the heat-seal initiation temperature and physical strength of LLDPE are much higher. In many cases, LLDPE film can be thinner than an alternative LDPE film. LLDPE resins can be blended with conventional LDPE in any ratio. The heat-sealing and physical characteristics of films made from blends range between the properties of either material. Processing of blends is much less demanding than processing straight LLDPE. LLDPE can also be blended with EVA copolymers to further enhance sealing properties.

Medium density polyethylene. MDPE is sometimes used as a component of multilayer structures where slightly higher heat resistance or barrier properties are desirable. MDPE is used as the inner component of boil-in-bag material and for some medical devices subjected to retort sterilization. LLDPE blends are replacing MDPE in many of these applications.

High density polyethylene. HDPE (see Film, high density polyethylene; Polyethylene, high density) is rarely used as the sealing medium in flexible packaging because of its high seal-initiation temperature and narrow seal range. Where heat resistance and high strength are required in special applications, eg, medical products, a rubber-modified HDPE is used.

Polypropylene. PP (see Polypropylene) is not widely used as a heat sealant except as a component of coextrusions used in special market areas. Polypropylene copolymers are used in coextruded BOPP films as the heat-sealant component and in retort pouch structures (see Retortable packages).

Ethylene copolymers. Copolymers of ethylene and vinyl acetate (EVA), acrylic acid (EAA), or methacrylic acid (EMAA) have properties that are very different from LDPE–LLDPE (see discussion under Ionomers). Each of the copolymers is available in a range of comonomer percentages. EVA is available with 4–30% vinyl acetate, for example. The acid copolymers, EAA and EMAA, provide excellent adhesion to metals, as do ionomer-modified acid copolymers. With increasing comonomer content, clarity and heat-seal range increase; crystallinity, stiffness, and heat-seal temperature decrease. They can all be used in multilayer structures as films that are laminated, as extrusion coatings, or as components of coextrusions. The copolymers cost more than LDPE and are used only if their specific properties justify the additional expense.

In summary, the variables considered when choosing a polyolefin sealant film are density, melt index, molecular weight distribution, homopolymer or copolymer, comonomer and percent comonomer, blend of resins, and film thickness. All of these materials can be modified with slip and antiblock additives, and they can be pigmented. Care must be exercised when using some of the copolymers if the packaged product is susceptible to picking up off-odors or flavors.

Sealing Properties of Heat Sealants

Seal-initiation temperature. This is the lowest temperature at which a seal can be achieved. Activation temperatures range from relatively low for waxes to relatively high for MDPE and HDPE. In multilayer structures, this involves not only the melting point of the sealant, but the conductivity of the other components of the structure. Most flexible materials are poor thermal conductors, which means that heat transfer is not rapid. In sealing operations in which the heat is applied to the outer surface of the material, more often from only one side, the amount of heat required is increased because of the insulation effect of the components. Aluminum foil is an excellent conductor, but because it transmits the heat laterally and takes the heat away from the seal area, more energy is necessary to effect a seal. Heat-seal initiation temperatures are determined by establishing a standard dwell time and pressure, and then progressively increasing the temperature until a seal is obtained. Information obtained in this way provides a starting point for establishing packaging machine conditions.

Seal range. This is the range of temperatures at set conditions of pressure and dwell time in which effective seals can be obtained. The seal-initiation temperature is at the bottom of the range; the top is the highest temperature at which a satisfactory seal can be obtained without deterioration of the seal or the structure.

Hot tack. Hot tack is the resistance to separation of a seal immediately after removal of the pressure and temperature of sealing. Waxes generally have poor hot tack; ethylene copolymer films, particularly ionomers, have good hot tack. This feature is very important in VFFS operations, where the product is dropped into the formed tube while the seal jaws are closed. The full weight of the product is then on the hot seal

tainers as against paper, plastics, or metal packagings. This is one area where U.S. legislation has influenced the EEC considerably, especially legislation in Minnesota, Oregon, and Washington.

Proposed directive on beverage containers. The European Parliament spent 1982 discussing the EEC Commission's proposals on beverage containers without getting very far. The issue has also become a political football with voting along party lines. The Left broadly supports the directive, and the Right opposes it. Votes swing either way, depending on who is present at the meeting in question. The Council of Ministers discussed the directive in June 1983, when seven member states voted in favor of it, two against (UK and Ireland), and the Italians were undecided.

Document 1-1187/82 drawn up on behalf of the committee on the Environment, Public Health, and Consumer Protection of the European Parliament calls on the Parliament to forward a new resolution to the Council and Commission proposing that the directive be replaced by a recommendation. The draft directive is faulted on several points, including failure to provide a basis or evidence for the proposed measures and for being unclear and badly drafted.

Well-informed people connected with the beverage industry think that a diluted version of the directive will eventually emerge without too restrictive an effect on the industries concerned, nor causing distortion of trade among member states. Legislation is also often threatened in the European countries that would control packaging to prevent "waste."

The prime function of packaging is to enable consumers to receive products in good condition at the lowest reasonable price. Any manufacturer, distributor, or retailer concerned with design or use of packaging has a responsibility to ensure that there is a regular review of packaging having regard to the economics of the total manufacturing/distribution chain and to consideration of reuse and disposal. Marketing and commercial considerations should be reconciled as far as possible with economy in the use of materials and energy and the environment.

1. Packaging must comply with all legal requirements.
2. In containing a product the package must be designed to use materials as economically as practicable, while at the same time having due regard to protection, preservation, and the presentation of the product.
3. Packaging must adequately protect the contents under the normal foreseeable conditions of distribution and retailing and also in the home.
4. The package must be constructed of materials that have no adverse effects on the contents.
5. The package must not contain any unnecessary void volume nor mislead as to the amount, character, or nature of the product it contains.
6. The package should be convenient for the consumer to handle and use. Opening (and reclosure where required) should either be obvious or indicated and convenient and appropriate for the particular product and its use.
7. All relevant information about the product should be presented concisely and clearly on the package.
8. The package should be designed with due regard to its possible effect on the environment, its ultimate disposal, and to possible recycling and reuse where appropriate.

Figure 5. UK Code for the Packaging of Consumer Goods

Excessive packaging. The principle criticism is probably the accusation that "packaging is excessive." These accusations are usually made where the selling and convenience factors are concerned. It must be remembered, however, that the decision by the manufacturer of a product to put conveneience or selling into his packaging results from the decision that this will provide an advantage over a rival product produced by a competitive company. Most manufacturers are very concerned to keep their packaging costs to a minimum, and the objective of any convenience or sales appeal in the packaging must be better sales for the product.

Moreover, the social implications of excessive packaging may be measured against a code for good retail packaging first suggested by the Japanese Packaging Institute. A code of practice along the lines of the Japanese suggestion has been produced by the United Kingdom Packaging Council (see Fig. 5), responsible for considering complaints referred to it by any interested parties who feel that a particular package breaks the guidelines set out in the Consumer Goods Packaging Code.

Industry on both sides, user and maker, in the UK and many parts of Europe would favor the self-regulating approach suggested here, rather than legislation, and any proposals for regulations in this field will be resisted. The Japanese and UK codes are working reasonably well, although a second tier of the codes, detailing the means for determining compliance is needed.

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LIDDING

Lidding is a very specialized aspect of flexible-packaging technology. The advent of portion packaging and dispensing packages created a need for flexible-packaging lidding materials, and liddings are frequently used to seal other types of packages, including semirigid containers. Lidding materials are rarely composed of just one layer. One or more layers provide physical properties, and other layers provide sealability. Generally, the ideal lid is one that is easily peelable, leaves no traces of sealant residue, and is tamper-evident (see Tamper-evident packaging). The sealant should melt at a relatively low temperature unless heat resistance is necessary for sterilization of the contents or reheating of a food product. Typical examples of lidding applications are shown in Figure 1.

The first considerations in the choice of a lidding must be

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the intended use. Some of the questions that should be asked follow:

Must the lid prevent contamination or aid in dispensing the product by being peelable or having push-through properties?

What are the requirements for gas, moisture-barrier and light protection?

Should the lid be fusion-sealed or peelable?

What temperature resistance is required of the lidding? Is the product to be packaged hot? Will retained heat be a problem?

Should the lidding be heat-sealable or pressure-sensitive? Will the use of cold-seal adhesives be advantageous?

Figure 1. Typical examples of liddings used in packaging applications. A, Transparent lidding sealed to opaque preformed cupcake tray; because of rapid turnover, this type of product requires only the minimal barrier properties of a peelable lidding. B, Peelable lidding sealed to a vinyl-coated aluminum cup for liquid unit-dose drug applications; this type of lidding should be easily peelable, but also requires tamper evidence. C, Snack package utilizing a flexible, peelable lidding with good gas- and moisture-barrier properties. D, Peelable cheese lidding with good gas- and moisture-barrier properties. E, Sample package of shampoo utilizing a flexible lidding sealed to a tray formed from polyethylene-coated PVC sheet; this is an example of a fusion seal. F, Lidding for a PVC preformed tray containing sutures packed in alcohol.

Should the lidding be tamper-resistant?

What type of container will the lidding cover, and how it be sealed to the container?

Will the lidding be left on during a temperature cycle sterilization)?

Must it also be resistant to electron-beam or nuclear st zation? If a lidding is used on a "cook-in-tray," will it b on during heating in a microwave or conventional o Liddings for cook-in-trays must also have good adhesi the tray while the product is in a refrigerated or fr state.

If the lidding is for an industrial application, it migh very easy to find an appropriate material. A typical exar would be a polyethylene-lined cannister filled with lubrica oil. An excellent lidding would be nylon/LLDPE (see Poly ylene, low density). However, if the application is for a product, the parameters of the barrier properties, compati ity of food and container, storage conditions, and when how the lid is to be removed must be evaluated. Meeting ap cable FDA regulations is another important considerat With medical products, the problems of contamination of packaged item also have to be very carefully considered.

How a lid is removed is of prime importance on many pa ages. A tab, or something to hold onto, is highly desiral Ideally, the lid should peel off in one piece. A residue of seal should be avoided if possible, but sometimes the peelabilit the lid is designed to come about by separating the coati from the base stock. Examples of good bases for lidding sto are paper/polymer/foil (see Multilayer flexible packaging) oriented polyester film (OPET), which also might have a b rier coating for improved protection.

In a paper/polymer/foil base stock, the polymer is genera polyethylene, but it can also be an ionomer (see Ionomers) ethylene–acrylic acid (EAA) to meet specific requirements. ionomer might be used to improve toughness or tear res tance. The next consideration is the protection of that side the foil that will face the container from the product bei packaged. If the product is inert to foil, protection is not nece sary, but because few products are chemically neutral, a ba rier layer next to the foil is generally essential. This can be simple as a vinyl coating, a vinyl film, a polyolefin film, or polyester film, depending on the product being packaged ar the type of protection needed. The heat-seal material is the applied over the protective layer (see Sealing, heat).

One of the simplest overwraps is nothing more than a co rona-treated (see Surface modification) OPET film (see Film oriented polyester). Polyester film is normally not heat-sea able, but corona treatment changes the surface so that it ca be heat-sealed to itself. The seal must occur at a temperatur near the polymer's melting point with high seal pressures. Th seal is a fusion-type seal, but it is brittle and tears open easily The chief use of this type of material is to overwrap schoo lunch trays or sandwiches. The physical protection is minimal but it does act as a cover to prevent direct contamination Another use is as a wrapper around frozen pizza. It is one o the most inexpensive liddings that can be sealed to a polyester coated tray, but it is normally not used in "ovenable" applica tions.

Another important group of materials for tray liddings is

OPET film coated with ethylene–vinyl acetate (EVA) applied from a solvent system or as an extrusion coating (see Extrusion coating). Normally, lower coating weights can be applied from a solvent system. The coating makes the material not just sealable to itself, but to a variety of other materials. It also seals at relatively low temperatures. EVA coatings do not form fusion seals, but the seals are peelable and usually removable in one piece. This type of lidding is very popular for polystyrene sandwich trays or other food trays. Tray packs of cheese and luncheon meat often use a PVDC-coated OPET film with an EVA coating.

Ovenable liddings are usually solvent-based polyester coatings applied to a polyester base film. The coating is used to provide heat sealability, and by proper selection of polyester resins used in the coating formulation, different seal ranges can be obtained and the degree of peelability regulated. Another route to obtaining peelability is to incorporate inert fillers into a coating which normally makes fusion seals. Polyester coatings, in addition to sealing to polyester materials, usually also seal to vinyl materials. For example, a polyester-coated OPET lid seals very well to a semirigid PVC blister.

PVC (see Poly(vinyl chloride)) films and solvent coatings are used as sealants on liddings where fusion seals to PVC semirigid stocks are required. The coating can be modified to provide peelability. Liddings for orange-juice portion packs have traditionally been aluminum foil with vinyl-type coatings which seal to a vinyl cup. The vinyl coating is inert to the acidic juice and is also good film-former to protect the foil from corrosion. Newer-type liddings are foil/film laminations (see Laminating machinery) coated with a peelable heat-sealed coating. Similar liddings are used for yogurt, but they also require good barrier properties to extend the shelf life of the product.

Medicinal products in pill form are sometimes packed in PVC trays with a push-through-type lidding for ease in dispensing (see Pharmaceutical packaging). The tray is designed with wide flanges around each pill so that every pill is fusion-sealed in its own compartment and kept free of contamination. The lidding is usually a vinyl-coated aluminum foil, at least 0.001 in. (25.4 μm) thick for good barrier properties, which is sealed to a tray formed from semirigid PVC. The other popular pill package is the strip package. The strip package generally incorporates a peelable lidding having several plies. The outer layer is usually paper (to provide a good printing surface) which is then mounted to foil either by extrusion coating or adhesive lamination. The sealant side of the lidding can be a film or coating or a combination. The actual construction depends on the barrier requirements. If an extremely good barrier is necessary for very long shelf life, the structure can contain Aclar (Allied Corp.), which has exceptional barrier properties (see Film, fluoropolymer).

Other medical uses for liddings are safety seals on bottles to prevent tampering. These are combinations of materials that form fusion seals and are destroyed, ie, delaminated, when opened so that resealing is difficult. A safety seal is often fabricated with aluminum foil and mounted to a bottle-cap liner stock (see Closure liners) with wax. The combination of safety seal and cap liner is die-cut and placed in the bottle cap.The filled and capped bottle is passed through an induction sealer that fuses the safety seal to the bottle and melts the wax adhesive layer so the two parts separate when the bottle is opened.

For medical devices (see Health-care packaging) that are to be ethylene oxide (ETO) sterilized, a popular packaging technique is to use a PVC tray with a Tyvek-coated lid. Tyvek (DuPont) medical-grade materials are porous to ETO gas, but not to bacteria. The sealant requires only limited heat resistance, but the web must be porous to allow the ETO to penetrate the Tyvek. Tyvek can be coated with a sealant in a pattern that does not change the pororsity of the lidding. Another variation is to use a coating that is heat-sealable but not fused in drying so that it does not form a continuous film and therefore maintains porosity. Yet another option is to put the sealant material on the forming web so the Tyvek does not have to be coated.

Aluminum foil is normally used in a lidding if excellent barrier properties and protection from light are required. If the package is to be microwave-heated or requires transparency, foil is normally replaced with a PVDC-coated film which also gives very good barrier properties. Sealing methods are usually conductive-type heat seals. Important exceptions to this are safety seals in conjunction with a bottle-cap liner which use induction-type sealing equipment.

Further refinements of lidding technology can be expected as part of the current focus on semirigid replacements for metal cans (see Retortable flexible and semirigid packages).

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LITERATURE. See Networks.

LITHOGRAPHY. See Printing.

gories: single-resin, unbalanced, and balanced films. Many films that are based on the performance properties of a single resin are coextruded for performance or cost reasons. Unbalanced structures typically combine a functional layer with a heat-seal resin. Balanced structures generally have the same heat-sealable resin on both sides of the film.

Single-resin structures. Single-resin films are coextruded for a variety of reasons. Many commodity film applications may not appear to be multilayer films, yet they actually have three or more distinct layers. Bakery, produce, and trash-bag films, for example, are often three-layer structures. The core material may contain pigment or recycled material, while virgin skin layers control surface quality and machinability. Single-resin coextrusions can also provide a differential coefficient of friction on the two surfaces.

Unbalanced structures. Typical of the unbalanced structures are films designed for vertical form/fill applications with a fin seal. A base resin such as high density polyethylene is augmented by an ethylene–vinyl acetate skin layer for sealability. For horizontal wrappers a polypropylene skin layer is sometimes selected for its higher thermal resistance. In another important unbalanced application, cast polypropylene, which has a limited sealing range, is combined with more sealable polyethylene for single-slice cheese wrappers (see Film, cast polypropylene).

There are multilayer films using only one polymer (A/A/A), unbalanced coextruded films with two or more polymers (A/B/C), and balanced multilayer structures with two or more polymers (A/B/C/B/A).

Balanced structures. Balanced coextruded structures typically have a core resin selected for its functionality plus two skin layers which are heat sealable. Oriented polypropylene films, for example, are increasingly coextruded instead of coated to attain machinable surfaces (see Film, oriented polypropylene). Frozen-food films are typically constructed with an EVA skin layer for enhanced sealability. Heavy-wall bags are regularly coextruded with LLDPE cores for impact strength and LDPE skins to limit the film's elongation under load. Primal meats are packaged in PVDC shrink film with EVA skins for seal integrity.

Two main applications which appear to be shifting from monolayer films to coextrusions are overwrap and stretch wrap (see Wrapping machinery, stretch film). Horizontal overwrap machines typically use an MDPE film or an LDPE–HDPE blend. Coextrusions can provide comparable overwrap machinability at lower gauge. Stretch wrap is difficult to produce as a single-layer structure without blocking. By splitting stretch wrap into a multilayer structure, its LLDPE core can be provided with controlled tackiness on the surface layer.

Table 1. Typical Coextruded-Film Structures

Outside layer	Core layer	Inside layer	Remarks
LDPE	white LDPE + recycle	LDPE	virgin skin layers control surface quality
HDPE	HDPE + recycle	EVA	EVA provides rapid fin seal machinability
EVA	LLDPE + recycle	EVA	EVA increases lap seal cycle time
LDPE	LLDPE + recycle	LDPE	LDPE limits film's elongation under load
EMA	OPP	EMA	oriented polypropylene sealability poor without coextruded or coated skin layers

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COEXTRUSIONS FOR SEMIRIGID PACKAGING

This article pertains to flat semirigid coextruded sheet which is a minimum of 0.010-in. (0.25-mm) thick (see Coextru-

ARTICLE 3

Table 1. Barrier Materials

Resin	O_2 Transmission rate[a]	Water-vapor[b] transmission rate	Mid-1985 price, \$/lb (\$/kg)
EVOH (Eval F, Kuraray)	0.035 [0.136]	3.8 [1.50]	2.41 [5.31]
PVDC (Saran 5253, Dow Chemical)	0.15 [0.583]	0.10 [0.04]	1.02 [2.25]

[a] $cm^3 \cdot mil/(100\ in.^2 \cdot d \cdot atm)$ [$cm^3 \cdot \mu m/(m^2 \cdot d \cdot kPa)$] at 73°F (23°C), 75% rh.
[b] $g \cdot mil/(100\ in.^2 \cdot d)$ [$g \cdot mm/(m^2 \cdot d)$] at 100°F (38°C), 90% rh.

sion machinery, flat). These coextruded sheet structures are thermoformed to produce high barrier plastic packages (see Barrier polymers; Thermoforming). A similar concept is used to produce high barrier plastic bottles except that the bottles are formed from coextruded multilayer tubes instead of flat sheet (see Blow molding).

The production of coextrusions for semirigid packaging was made possible by technology developed in the late 1960s and early 1970s (1, 2). Utilization of this technology was initially limited to "simple" structures such as two-layer systems (a general purpose polystyrene cap layer on a high impact polystyrene base layer) for drink cups. Commercialization of high-barrier coextrusions occurred in the 1970s in Europe and Japan. Large-scale commercial barrier coextrusion applications did not surface in the United States until the 1980s. For purposes of this discussion, barrier materials are defined as those that exhibit an oxygen transmission rate of less than 0.2 $cm^3 \cdot mil/(100\ in^2 \cdot day \cdot atm)$ [0.777 $cm^3 \cdot \mu m/(m^2 \cdot d \cdot kPa)$] (see Barrier polymers). Other techniques that can be used to produce multilayer barrier structures are coating and lamination (see Coating equipment; Laminating). Some advantages coextrusion offers versus these other two methods are thicker barrier layer capability, single-pass production, barrier layer sandwiched between cap layers, and generally lower cost. The potential markets for packages formed from these high-barrier coextrusions include both low- and high-acid food products sterilized by aseptic, hot-fill, or retort methods. These markets obviously represent a significant opportunity for barrier coextrusions.

Barrier Materials

Based on the barrier definition above, only two commercially available thermoplastic resins can be considered as barrier resin candidates for these extrusions. These are ethylene–vinyl alcohol (EVOH) (see Ethylene–vinyl alcohol) and poly(vinylidene chloride) (PVDC) (see Vinylidene chloride copolymers). The barrier properties of specific grades of these two materials are listed in Table 1. The resins identified in the table are currently the highest barrier commercially available coextrudable resins of their respective polymer classes. Other formulations of both resin types are available offering certain property and processing improvements at the sacrifice of barrier properties.

The most significant technical issue concerning the use of EVOH as a barrier material is its moisture sensitivity. The material is hygroscopic, and its barrier properties are reduced as it absorbs moisture. The importance of this property to the food packager is dependent upon the sterilization process, food type packaged, and the package storage conditions. The most severe conditions are encountered during retort processing (see Canning, food). Special consideration to coextrusion structure design and post-retorting conditions may be required to achieve the desired oxygen barrier for packages produced from EVOH coextrusions (3).

PVDC is not moisture sensitive and does not exhibit the deterioration of barrier properties shown by EVOH. The challenges associated with using heat-sensitive PVDC are faced by the coextruded sheet producer. Equipment and process design are critical to the production of coextrusions containing PVDC. Concern relating to the reuse of scrap generated in the production of coextrusions based on PVDC is a real economic issue. Development of new material forms and recycle-containing structures is underway with commercialization targeted for 1985 (4). In the meantime, resin manufacturers are working on the development of other types of barrier materials for coextrusion applications (5).

Structural Materials

The materials generally used to support the barrier resins in coextrusions are listed in Table 2. The maximum process temperature listed is the highest sterilization temperature that packages based on these resins should experience. Polystyrene, polypropylene, and the polyethylenes are the predominant structural materials used in coextrusions for semirigid

Table 2. Structural Materials

Resin	Maximum process temperature, °F (°C)	Mid-1985 price \$/lb (\$/kg)
polystyrene	195 (90.6)	0.49–0.51 (1.08–1.12)
polypropylene	260 (127)	0.43–0.47 (0.95–1.04)
high density polyethylene	230 (110)	0.44–0.50 (0.97–1.10)
low density polyethylene	170 (77)	0.40–0.44 (0.88–0.97
polyester, thermoplastic (heat-set)	>260 (>127)	0.63–0.67 (1.39–1.48)
polycarbonate	>260 (>127)	1.69–1.81 (3.73–3.99)

packaging applications. Structural resin selection is dependent upon use requirements, coextrusion processability, and container-forming considerations.

Polystyrene (see Polystyrene) exhibits excellent coextrudability and thermoformability. It can be used in applications requiring low temperature processing and in some hot-fill applications. Polypropylene (see Polypropylene) is also excellent from a coextrusion-processing standpoint, but it requires special forming considerations. Deep-draw containers from polypropylene-based sheet are most commonly formed using solid-phase forming techniques. Polypropylene can be retorted; but some grades exhibit poor low temperature impact characteristics which limit their use in applications requiring resistance to refrigerated or freezing temperatures.

High density polyethylene (see Polyethylene, high density) offers a significant improvement in low temperature properties compared to polypropylene, but its suitability in applications requiring retort processing is marginal. Low density polyethylene would be incorporated in coextrusions requiring good heat sealability (see Sealing, heat) for applications involving low-temperature-fill conditions.

Although coextrusions based on crystallizable polyester (see Polyesters, thermoplastic) and polycarbonate (see Polycarbonate) are not commercially available at this time, these materials are included as structural materials because of their future potential in retort applications. The success of these relatively expensive materials will be dependent on the cost and performance achieved. Considerable developments of coextrusion and forming techniques need to be completed prior to commercialization of coextrusions based on polyester and/or polycarbonate.

Applications

Three representative commercially coextruded structures are shown in Table 3. The transition layers in these structures are materials used to ensure the integrity of the coextrusion. The technology of transition layers is complex and maintained as proprietary by coextrusion manufacturers. The first structure, which uses polystyrene as both cap layers, finds use in form/fill/seal applications because of the particularly good thermoformability of polystyrene (6) (see Thermoform/fill/seal). The second structure has one polystyrene cap layer to maintain thermoformability and one polyolefin cap layer. The polyolefin layer in this case would be the food-contact layer. This structure would comply with the current FDA regulations for aseptic H_2O_2 package sterilization (see Aseptic packaging). The resins that comply with current FDA regulations for H_2O_2 sterilization are polyethylenes, polypropylenes, polyesters, ionomers (see Ionomers), and ethylene vinyl acetates (EVA). Petitions have been submitted for FDA clearance of polystyrene and ethyl methyl acrylate (EMA) as food-contact layers as well. Containers formed from this structure, with polypropylene as the food-contact surface, can also be hot filled (7).

The last structure shown in Table 3 has the most potential of those listed because it can be used in applications including retort processing. The primary market target for coextrusions with polypropylene as the cap layers is processed foods currently in metal cans (8, 9).

In addition to the food-packaging markets, barrier coextrusions can be utilized in the medical (see Health care packaging), pharmaceutical (see Pharmaceutical packaging), and industrial packaging markets where barriers to oxygen, moisture, and hydrocarbons are required.

Table 3. Commercial Coextrusions

Structure	Application
polystyrene	form/fill/seal
transition	preformed containers
barrier	hot fill
transition	
polystyrene	
polystyrene	form/fill/seal
transition	preformed containers
barrier	H_2O_2 aseptic
transition	hot fill
polyolefin	
polypropylene	preformed containers
transition	H_2O_2 aseptic
barrier	hot fill
transition	retort
polypropylene	

Economics

Simply utilizing resin prices to calculate a material cost for a coextruded sheet structure can be unreliable in determining the economics of barrier plastic packages. Using material prices only to compare the economics of several coextruded sheet structures based on different resins can result in erroneous conclusions. Items such as required equipment costs, coextrusion output rates, package-forming method and rates, amount of scrap generated, amount of scrap reutilized, container design, and container performance are some of the cost considerations that can be dissimilar for different coextruded sheet structures. Economic comparison of various coextruded barrier packages with alternative packaging materials should be based on a total packaging systems analysis. The current commercial applications and market tests underway show that packages from coextruded sheet offer economic and/or performance advantages versus other packaging materials.

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Table 4.8 Advantages and disadvantages of horizontal f.f.s. pillow and sachet packs (adapted from material presented by A. P. Benson, Institute of Packaging Education Course, February 1980)

Advantages	*Disadvantages*
Pillow pack	
Good product volume/pack size ratio.	Unsuitable for powders or granular products.
Very wide range of materials from inexpensive coated films and papers to complex laminates.	Limited size range versus conventional overwrapping machines.
Relatively simple machine construction and comparative low cost of packaging machinery.	
Easy adjustability for a wide range of sizes.	
Smooth continuous motion action, giving options ranging from high output (600 ppm lines) to low output (40 ppm lines) high versatile units.	
Sachet pack	
Short product drop (compared to vertical sachet machines) means reduced filling time and high line speeds (up to 400 ppm).	Product volume/pack size ratio is not as good as on pillow pouch machines.
Pack forming and sealing is performed away from the filling station(s) so that sealing efficiency is not impaired by product trapped between the seals.	Inexpensive, "unsupported" wrapping materials cannot generally be used, since the operating principle demands the use of more rigid, laminated materials.
Pack rigidity superior to pouch-style pack.	Packaging machinery tends to be significantly more expensive than pillow pouch packaging machinery.
High degree of seal efficiency from four-sided fin-seal system.	
Automatic filling of multiple product loads is possible.	

web over the open tray so as just to cover the flanges of the trays to permit a heat seal closure (figure 4.46). The web of filled and closed packages is then punched out to form individual packages, or may be slit at intervals to give a number of units joined together. Such machines operate at speeds of from 6 to 20 cycles per minute, and the number of packages produced will depend on the number formed per cycle which in turn is generally dependent on the area they occupy.

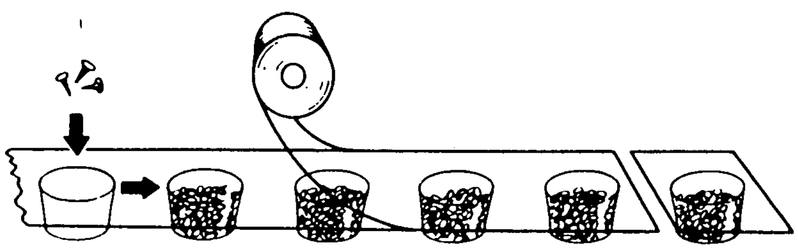

Figure 4.46 Thermoformed f.f.s. packs.

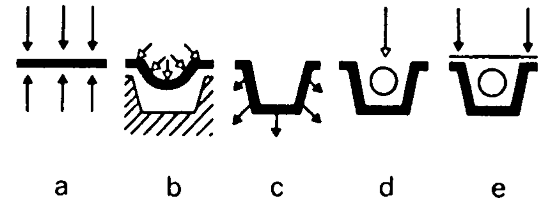

Figure 4.47 The steps in making thermoforms. (*a*) Heating; (*b*) forming; (*c*) cooling; (*d*) filling; (*e*) sealing.

Figure 4.47 illustrates the steps in the packaging operation. Heating, forming, cooling and sealing are the most important steps in producing the thermoformed (deep-drawn) package. Thermoforming the film is especially important. Figure 4.48 contains a summary of the possible forming methods, of which the most commonly used are negative vacuum forming, with or without plug assist and negative compressed air forming, with or without plug assist. In these methods, the heated film is formed in a mould (negative forming). In vacuum forming, the force is provided by the difference in pressure between the evacuated mould and the atmosphere of 1 bar (1 kg/sq. cm). In compressed air forming, forming pressures of 6–8 bars are common.

Vacuum forming results in irregular wall thicknesses in a deep-drawn cavity (figure 4.49). The most uniform wall thickness distribution is produced by means of compressed air forming with plug assist. Compressed air forming without plug assist also results in more uniform wall thicknesses than with vacuum forming. However, the machinery required for this method is more complicated—and more expensive—than comparable machines for vacuum forming.

The requirements for processing laminated films (PVC-PVDC, PVC-PFC, PVC-PE-PVDC), and for producing more complicated shapes, are basically different. As a result of the required high forming force in the partially limited forming temperature range, only the compressed air forming method, either with or without plug assist, can be employed. Mechanical pre-stretching is always required for complicated shapes. Compressed air forming alone does not provide uniform distribution of the material in the deep-drawn cavity. There are six main materials used for thermoforming.

(i) *Rigid PVC film (polyvinyl chloride)*. This is produced primarily by calendering. It has good thermoforming properties, and is generally processed clear, coloured and printed. It can be sealed by HF, ultrasonic, radiation, heat impulse and heat contact methods.

(ii) *Polystyrene film*. This is produced almost exclusively by extrusion. It has good thermoforming properties, similar to rigid PVC film. Clear, stretched

ARTICLE 4

From: The Wiley Encyclopedia of Packaging Technology 1986, John Wiley & Sons

vide a package with a valve system that will allow a product such as coffee to outgas without causing the package to rupture or balloon (see Vacuum coffee packaging).

Hesser also makes a system that produces a container similar to a composite can. This machine takes a laminate from rollstock and forms a rectangular body. It then attaches one end, fills the container and seals a lid to it. This equipment has the capability to make an aseptic package.

Horizontal form/fill/seal is an extremely dynamic segment of the packaging industry, for materials and equipment are continually improving, presenting new opportunities. New coextruded structures offer barrier and machining possibilities that are expanding the range of food products that can be packaged in flexible film (see Coextrusions for flexible packaging; Coextrusions for semirigid packaging). Aseptic packaging is another growth area that will add new dimensions to food packaging. In conjunction with the advance in these technologies are equipment developments that will provide a basis for expansion and cost reduction.

General References

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PMMI Packaging Machinery Directory, Annual, Packaging Machinery Manufacturers Institute. Washington, D.C.

J. H. Briston, L. L. Katan, and G. Godwin, *Plastics Films*, Longman, New York, 1983.

F. A. Paine and H. Y. Paine, *A Handbook of Food Packaging*, Blackie and Son Ltd., Glasgow, 1983.

R. F. Barnsley
Bard Associates

FORM/FILL/SEAL, VERTICAL

The term form/fill/seal means producing a bag or pouch from a flexible packaging material, inserting a measured amount of product, and closing the bag top. Two distinct principles are utilized for form/fill/seal packaging; horizontal (HFFS) (see Form/fill/seal, horizontal) and vertical (VFFS). Generally, the type of product dictates which machine category applies. This article deals specifically with VFFS equipment, which forms and fills vertically. It is used to produce single-service pouches for condiments, sugar, etc, as well as bags for retail sale and institutional use. The range of products and sizes is very large.

Package Styles

VFFS machines can make a number of different bag styles (see Fig. 1):

A pillow-style bag with conventional seals on the top and bottom, and a long (vertical) seal in the center of the back panel from top to bottom. The long seal can be a fin seal or a lap seal (see Fig. 1 a and b)

A gusseted bag with tucks on both sides to make more space for more product and maintain the generally rectangular shape of the filled bag (see Fig. 1 c). This style is used inside folding cartons for cereal and other dry products (see Bag-in-box, dry product)

A three- or four-sided seal package is similar to those made on HFFS machinery (see Fig. 1 d).

A stand-up bag (flat bottom, gabletop) of the type that used to be common for packaging coffee.

Other special designs such as tetrahedrons, parallelograms, and chubs (see Chub packages).

A flat-bottom bag needs a relatively stiff material to hold its desired shape, but any type of machinable material can be used to make a pillow-style bag. Various options are available, such as a hole punch for peg-board display, header labels which are an extension of a standard top of a bag, carry-handles for large consumer-type packages, and special sealing tools for hermetic seal integrity.

Materials

Two types of packaging materials are suitable for VFFS: thermoplastic and "heat-sealable" materials. Polyethylenes (thermoplastics) require a special bag-sealing technique. Polyethylene films must be melted under controlled conditions until the areas to be attached to each other are fused. The operation is analogous to welding metals. Heat is applied to fuse the materials and then a cooling process allows the seal to set. The sequence for making good seals requires careful control in order to get quality-seal integrity. Impulse sealing is used to seal thermoplastics on VFFS machines. A charge of electricity is put into a Nichrome wire which heats to a pre-established temperature (governed by material thickness) that will melt and fuse the materials. Since thermoplastics become sticky when melted, the Nichrome wire is covered by a Teflon (Du-Pont Company) sheath. The principle of impulse sealing does not require any specific tooling pressure.

Thermoplastic materials are generally used when a high degree of product protection is not required and low material cost is important. Polyethylene materials have some porosity and are not ideal for applications where hermetic seals are

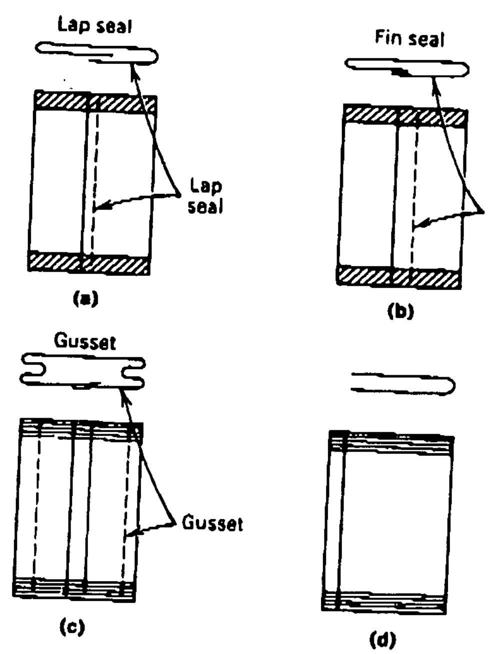


Figure 1. Selected package styles on VFFS machinery. (a) and (b), Pillow style; (c), gusseted style; (d) three-sided seal.

ARTICLE 5

necessary for good shelf life, product freshness, gas flushing, etc. They are used, for example, for frozen foods, chemicals, confectionary items, fertilizers, and peat moss.

The class of "heat-sealable" materials or "resistance seal films" includes paper and cellophane as well as some coextrusions and laminations. Because these materials do not melt at sealing temperatures, or do not melt at all, they require a heat-seal layer that provides a seal with the right combination of time, temperature, and pressure. The sealant layer can be on one or two sides of the web, depending on the desired package configuration (see Multilayer flexible packaging).

A fin seal (see Fig. 1) can be made of materials with sealing properties on one side only, because the "heat-scalable" surface seals to itself. This seal is effective for powder products that need the seal to eliminate sifting. It is also a good seal if hermetic-seal integrity is important, as in gas-flush packaging. A lap seal uses slightly less material, but it requires sealing properties on both sides because the lap is made by sealing the inner ply of one edge to the outer ply of the other edge.

Machine Operation

A VFFS machine produces a flexible bag from flat roll stock. Material from a roll of a given web dimension is fed through a series of rollers to a bag-forming collar/tube, where the finished bag is formed (see Fig. 2). The roller arrangement maintains minimum tension and controls the material as it passes through the machine, preventing overfeed or whipping action. The higher the linear speed of the film, the more critical this handling capability becomes.

The bag-forming collar is a precision-engineered component that receives the film web from the rollers and changes the film travel from a flat plane and shapes it around a bag-forming tube. The design of the bag-forming collar can be engineered to get the optimum efficiency from metallized materials, heavy paper laminates, etc. As the wrapping material moves down around the forming tube, the film is overlapped for either the fin or lap seal. At this point, with the material wrapped around the tube, the actual sealing functions start. The overlapped material moving down (vertically) along the bag-forming tube will be sealed. The packaging material/film advances a predetermined distance that equals the desired bag-length dimension. The bag length is the extent of the material hanging down from the bottom of the tube. The bag width is equal to ½ of the outside circumference dimension of the tube. After the film advance is completed, the bag-sealing and -filling completes the remainder of one cycle (film advance/fill/seal). There are two sets of tooling on the front of the machine. One of the sealing tools, the vertical (longitudinal or back) seal bar, is mounted adjacent to the face of the forming tube. Its function is to seal the fin- or lap-longitudinal seal which makes the package material into a tube.

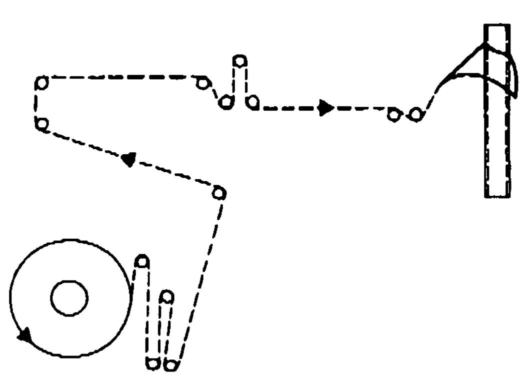


Figure 2. Typical film feed path through a vertical form/fill/seal machine.

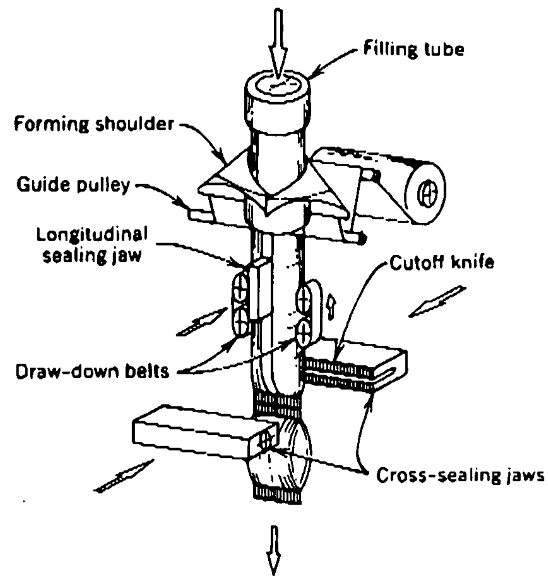


Figure 3. Typical VFFS configuration.

The other set of tooling, the cross (end) seal, consists of a front and rear cross-sealing jaw that combines top- and bottom-sealing sections with a bag cutoff device in between. The top-sealing portion seals the bottom of an empty bag suspended down from the tube, and the bottom portion seals the top of a filled bag. The cutoff device, which can be a knife or a hot wire, operates during the jaw closing/sealing operation. This means that when the jaws open, the filled bag is released from the machine. All vertical bag machines utilize this principle to make a bag (see Fig. 3).

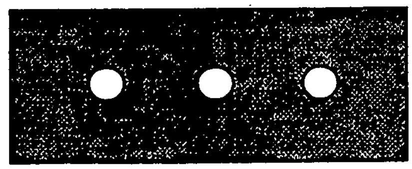
Machine Variations

Film transport. Two distinct machine designs are used for transporting the packaging material/film through the machine. The traditional design clamps the material with the cross-seal jaws and advances the material by moving the cross-seal jaws down. This is called a "draw bar" (reciprocating up-down cross-seal jaws). The other is a drive-belt principle for film advance, which leaves the cross-seal bars in a fixed horizontal position with only open-close motion. The belt-drive film-advance principle has been shown to be the most versatile design for high speed packaging and simplicity of operation, and a number of companies have converted to this principle.

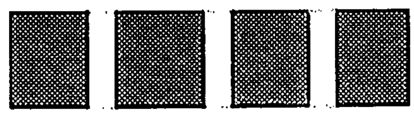
Power. There are several approaches to providing power for material/film transport and the filling and sealing operations: all electromechanical; electromechanical/pneumatic; and electromechanical/pneumatic/vacuum.

The electromechanical vertical-bag machine incorporates a cam shaft with a series of cams to operate the various functions. The package material/film drive motion works off a mo-

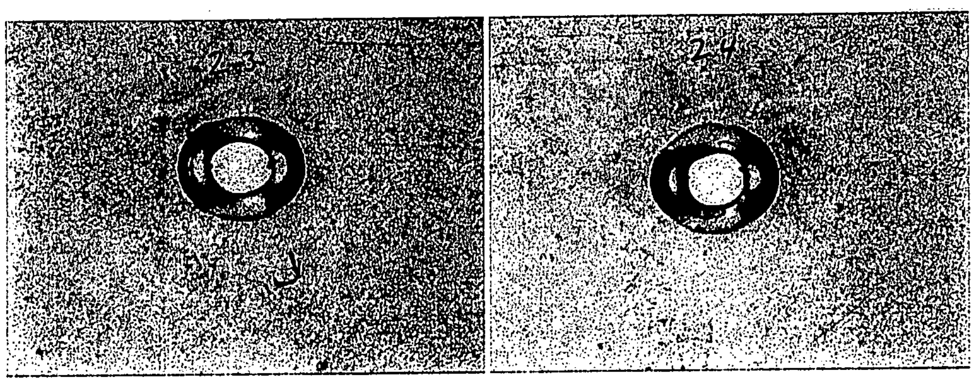
Figure 1. Structure of a typical microperforated film as described in my invention: (a & b) are drawings showing a surface view (a) and a cross sectional view (b). Light micrographs of actual 120-micron diameter microperforations in a polypropylene/polyethylene laminate are shown in (c).



(a)

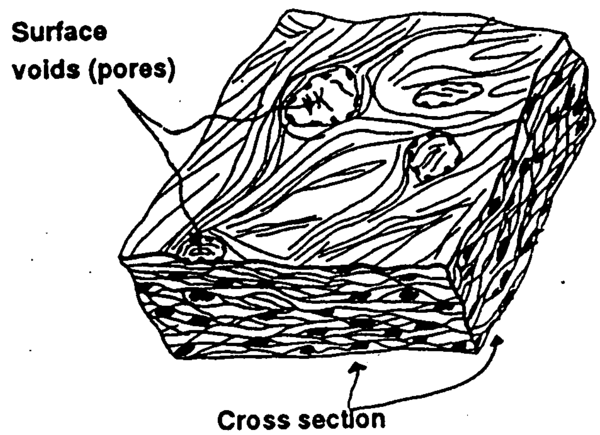


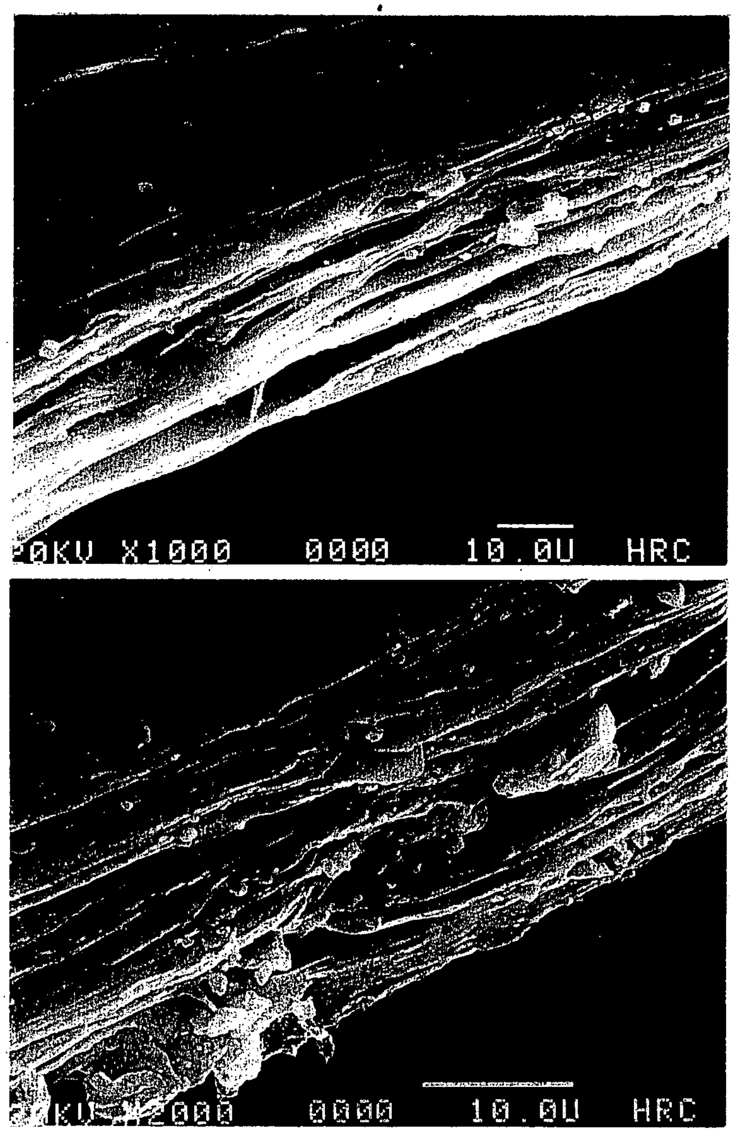
(b)



(c)

Figure 2. Drawing of a microporous film showing irregular void (pores) in the surface. The cross section reveals a tortuous pore structure with a network of interconnecting pores. Dark particles in the cross section are filler particles, typically $CaCO_3$ or silica. From U.S. Patent 3,903,234, 1975. Scanning electron micrographs of an actual cross section of this type of microporous film are attached.





Continuation of Figure 2:

Scanning electron micrographs (1000x and 2000x) showing the surface and cross section of a typical <u>microporous</u> film. Note that unlike microperforated films, the micro-voids or pores in microporous film are not capillary in structure, i.e., they do not follow a straight path through to the other surface of the film.

E. Marston Associates
603/890-6587

Del Monte

Del Monte Fresh Produce N.A., Inc.

To: Manny Zantua

Date: January 4, 1999

From: Denise Cavanaugh

cc: Dan Funk

Subject: Banana packing trials

As you are well aware, on 12/9 we re-packed bananas here at Manatee with 4 different treatments. These bananas were held for two weeks. On 12/21 the gas analysis were taken and sent to Dr. E.V. Marston for measurements. The treatments were then sent to Plant City for processing. On 12/28, I retrieved one sample of each treatment for quality evaluation. The results are as follows:

Treatment 1 Banavac 1.5 mil LLDPE was ripped before gassing, and upon arrival here at the port were a uniform stage 6. 6

Treatment 2 Banavac 0.8 mil HDPE was ripped before gassing and the results were also a uniform stage 6. 6

Treatment 2 Banavac 0.8 mil HDPE which were not ripped before gassing was a 1 ½ upon arrival here at the port. As of today, after being held at ambient temperature for 6 days, they are a uniform stage 4 ½. 1 ½

Treatment 3 Type C184 Test Bag which were not ripped before gassing, were a uniform stage 5 ½. 5 ½

Treatment 4 Type A168 Test Bag which also were not ripped before gassing, were a uniform stage 4. 4

If there are any other questions, please contact me.

Thanks and best regards

Dr. Marston:
I'm somewhat surprised by overall results. I'll try to send you a short letter before I start a 1-month travel period Friday.
DJ

Port Manatee, 200 Del Monte Way, Palmetto, FL 34221 6809 Telephone (941) 722 8060 Fax (941) 722 7075

Serial No. 09.528,290,
Atty. Dkt. No. MARS93

LETTER 1

DEL MONTE FRESH PRODUCE COMPANY
P.O. BOX 149222 - CORAL GABLES, FL 33114-9222
R&D/QA DEPARTMENT FACSIMILE TRANSMISSION
FAX (305) 445-7612 - TELEPHONE (305) 520-8089

TO: Dr. Elizabeth Marston
(603) 890-6735

DATE: January 12, 1999

FROM: D.W. Funk

cc: D. Cavanaugh
M. Zantua

NUMBER OF PAGES 1 (including cover)

SUBJECT: Banana Bag Trial at Port Manatee

Ripening trials carried out at our Plant City, FL, facility showed that ethylene penetrated both test bags to approximate standard ripening. And, as anticipated, banana ripening was delayed when the fruit was enclosed within intact standard Banavac bags. It is important to note that, at least in pressurized rooms, the fruit ripening was not accelerated by the test bags – which might have indicated interference with cooling.

The gas sampling analyses are of more interest to me. Literature suggests that the standard 1.5 mil PE Banavac bag maintains a modified atmosphere of approximately 2% oxygen/5% carbon dioxide. Your data show about 18% oxygen/2% carbon dioxide for these bags, pretty similar to data, which we had developed for melons. I'm now questioning the validity of information in the literature, and have asked Cryovac to talk with me about this situation.

Both test bags performed better than the banavac standards, but I don't know if the differences are of significance. And I'm at a loss to understand why perforated bags should maintain a higher level of carbon dioxide under these conditions. This trial has shown that I have to investigate CA/MA influences on fruit maturity more thoroughly.

Regards.

Dan

DWF1828: omr

LETTER 2

May 1, 2001

To: Rob Rudman / BOSKOVICH FARMS
From: Steve Layton/SOCOPAC

Re: Iceless Green Onion Packaging Trials

1st Trial Summary:

Bunched iceless green onions were packed and stored for 29 days at BOSKOVICH FARMS, Oxnard in February of this year. Three modified atmosphere packages were tested, The EXTEND™ mechanically perfed liner bags and two laser perfed (Micro Cap™) liners. The test results are shown on the attached report dated 3/1/01 (please see disc).

The test results showed that all three liner specifications provided salable green onions after 15 days refrigerated (34 F°) storage with onions that had initially been shipped, top iced, from Mexico.

After 21 days, the mechanically perfed and "A" laser perfed bags began to dehydrate, slime and curve. The "B" laser perfed bags remained clean and salable. After 29 days the "B" laser perfed bags evidenced 5-10% stem decay while the "A" laser perfed bags and mechanically perfed bags were definitely unsalable.

It was decided to run a second storage trial with two additional laser perforation specifications, further fine tuning the specifications based on the initial test results.

2nd Trial Summary:

A second storage trial was run April 4 through May 1, again on Mexican, top iced bunched onions. Four cartons each were packed in laser perfed styles "C" and "D" liners (MICRO-CAP™) and 1 carton was packed in a mechanically perfed (MP) locally supplied liner. Onions were graded as having 5-10% physical damage when packed.

Observations were made after 21 days (4/25) and again 28 days (5/1) at 34 F°. Louis Davilla was present during all the observations.

Results After 21 Days:

	Odor	Color	Texture	General
MICRO-CAP "C":	0	exclnt	crisp	salable no decay
MICRO-CAP "D":	0	exclnt	crisp	salable no decay
MP:	0	slight darkening	slight softening	salable, slight dehydration

Both Louis and I felt that the onions looked better when opened after 21 days then when packed. All were considered salable, with the onions packed in the "C" liner looking slightly sounder.

Results after 28 Days:

	Odor	Color	Texture	General
MICRO-CAP "C":	0	exclnt	sftning	salable 5% decay
MICRO-CAP "D":	0	exclnt	sftning	marginal, 15% decay
MP:	0	drkning	sftning	bulb slime, 20-25% stem decay, unsalable

The MICRO-CAP "C" liner was observed as the better liner after 28 days storage, producing a salable but slightly stressed appearance. This is thought to be due to the liners ability to micro-manage the internal atmosphere in the package. Mechanically perfed bags with physical holes, somewhat reduce dehydration however the holes are unable to specifically manage internal package atmosphere. It can be surmised from both tests that a month is the optimum storage time that can be expected from MICRO-CAP liners at the storage conditions noted with onions of the quality and condition packed in both tests.

Photos of the 28 day test results on the second trial are attached on disc. (jpg files)

Del Monte Fresh Produce Company

I[illegible] / INTRA-COMPANY CORRESPON[illegible]CE

TO: T. Young/J. A. Yock

DATE: Jul. 31, 2001

FROM: Manny
M. I. Zantua

COPIES:
J. P. Bartoli/C. Abarca
D. Murray/D. Marin
O. Pessoa/B. Medrana
G. Restrepo/R. Cariel
J. Clark/P. Franceri
J. Lopez/R. Paningbatan

SUBJECT: **Micro-CAP™ Plastic Banana Bag Trials in Europe**

Highlights in this report are based on the following evaluations in Europe:

1. Cameroon banana evaluated in U.K. by John Clark 06/12/01.
2. Costa Rican banana evaluated in U.K. by John Clark 06/27/01.
3. Colombian banana evaluated in Antwerp by Ricardo Carriel 07/05/01.
4. Costa Rican banana evaluated in Italy by Paolo Franceri 07/19/01.

History. In 1999, post-harvested storage and ripening of banana in Port Manatee, Tampa were evaluated in two micro-perforated bags (Type C184, Type A168) and compared them to the regular 1.5 mil LLDPE Banavac bag. Micro-perforated bags allowed a build-up of carbon dioxide 4-6% (or reduction of oxygen to 17-16%, correspondingly), but only about 2% (18% oxygen) in the regular Banavac bag. After two-week storage, we were able to ripen the fruit normally without tearing the micro-perforated bags – implying that ethylene gas permeates through the micro-pores (fruit inside intact Banavac bag did not ripe). One week after ripening, fruit inside the Type A168 was uniform color 4 while the ripped Banavac bag was color 6 – indicating that color development is slower (or increasing ripe shelf life of banana) in the micro-perforated bag.

Crown rot/mold on Colombian fruit continued to be a problem in Germany. Aside from post-harvest fungicide, shipping banana in controlled or modified (Banavac) atmosphere reduces crown rot incidence. The objection of Banavac packaging in Germany is the extra cost and/or handling involved in ripping the bag just before gassing. The use of micro-perforated bag will resolved both the crown rot/mold and handling problem on Colombian fruit going to Europe. These trials were therefore established to evaluate the effects micro-perforated bags on crown rot and mold control and ripening of the fruit.

Summary of findings is as follows:

- Cameroon banana in U.K. ripened uniformly in Micro-CAP™ bag similar to that of ripped Banavac bag, but color is about ½ less in the former. Un-ripped banavac did not ripe. No problem reported on crown rot or mold in both bags.

- Costa Rican banana in U.K. ripened uniformly inside Micro-CAP™ and cut Banavac bags, but the former has more under color boxes supporting the slower color development. No problem reported on crown rot and mold in both bags. Un-ripped banavac did not ripe.

erial No. 09/528,290,
tty. Dkt. No. MARS93

LETTER 4 (1/2)

- Colombian banana in Belgium was ripened with a slow ripening process in a conventional ripening room. One week after gassing fruit inside Hydropack, Micro-CAP™ and Polypack color stages were between 3-5 in the different bags. Polypack and Hydropack fruit has some crown turning yellow, whereas, 100% of the crown in the Micro-CAP™ bag was full green. This is a very significant finding. Some crown mold was observed on the crown of clusters without post-harvest fungicide in the Hydopack bag.

- Costa Rican banana in Italy has color stage 3 after 5 days in Banavac bag but same color stage after 7 days in Micro-CAP™ bag. No problem reported on crown rot/mold in both bags.

In short, the initial data obtained in 1999 in Manatee are being confirmed by these different trials sent to Europe. Modified atmosphere packaging in either 1.5 mil LLDPE Banavac or Micro-CAP™ is helping in the control of crown rot/mold. The handling problem of Banavac in Germany can be resolved by using Micro-CAP™ bag.

Acknowledgement

The valuable help, support and preparation of the trials extended by the tropical operations (G. Restrepo, O. Pessoa, D. Marin, B. Medrana) and actual fruit evaluation in Europe (A. Abarca, J. Clark, R. Carriel, P. Franceri) are very much highly appreciated. Without them, it will be impossible to obtain this very significant information.

Del Monte

Del Monte Fresh Produce Company

August 1, 2001

Dr. E. V. Marston
EV Marston & Associates
18 Wilson Road
Windham, NH 03087

Dear Dr. Martson

Attached you will find the results of the Micro-CAP™ trials in Europe. Similar to our initial trial, the results are very positive. Can the micro-perforations be placed close to the bottom of the bag so they will be close to the shoulder or at the side of the box for complete and constant exposure?

In using the data presented in this report, we must request that the name "Del Monte" or "Del Monte Fresh Produce Company" not be used in the promotion and/or sale of your Micro-CAP™ plastic bag material.

Thank you very much for giving us again the opportunity to test your micro-perforated bag. We will continue further experimentation on the remaining bags that you have given us.

Sincerely,

M. I. Zantua

M. I. Zantua

Cc: Tom Cowan
PPC Industries, Inc.

Serial No. 09/528,290,
Atty. Dkt. No. MARS93

LETTER 5